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Colonization of Unionid Bivalves by the Zebra Mussel, *Dreissena polymorpha*, in Pool 26 of the Mississippi River

Windrow Formation of Two Snails (Families Viviparidae and Pleuroceridae) Colonized by the Exotic Zebra Mussel, *Dreissena polymorpha*

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Windrow Formation of Two Snails (Families Viviparidae and Pleuroceridae) Colonized by the Exotic Zebra Mussel, *Dreissena polymorpha*

by

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Preface

The Long Term Resource Monitoring Program (LTRMP) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The LTRMP is being implemented by the Environmental Management Technical Center, an office of the National Biological Service, in cooperation with the five Upper Mississippi River System (UMRS) states, Illinois, Iowa, Minnesota, Missouri, and Wisconsin, with guidance and Program responsibility provided by the U.S. Army Corps of Engineers. The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers.

The mission of the LTRMP is to provide decision makers with information to maintain the UMRS as a sustainable large river ecosystem given its multiple-use character. The long-term goals of the Program are to understand the system, determine resource trends and impacts, develop management alternatives, manage information, and develop useful products.

Invertebrate monitoring and research are activities routinely conducted under the LTRMP (Strategy 2.2.7, *Monitor and Evaluate Selected Macroinvertebrate Populations and Communities* in the LTRMP Operating Plan [USFWS 1992]). Zebra mussel studies have been identified as particular areas of emphasis (Strategy 1.3.2, *Select New Problems for Research*; Sub-Strategy 3, *Assessment of Zebra Mussel Invasion of Upper Mississippi River System*) in the LTRMP Annual Work Plan for Fiscal Year 1994 (USFWS 1993).

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U.S. Fish and Wildlife Service (USFWS). 1992. Operating Plan for the Upper Mississippi River System Long Term Resource Monitoring Program. Environmental Management Technical Center, Onalaska, Wisconsin, Revised September 1993. EMTC 91-P002. 179 pp. (NTIS #PB94-160199)

Colonization of Unionid Bivalves by the Zebra Mussel, *Dreissena polymorpha*, in Pool 26 of the Mississippi River

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ABSTRACT

The relationship between 18 species of native unionid bivalves and the exotic zebra mussel, *Dreissena polymorpha*, was explored at a monitoring site in Pool 26 of the Mississippi River. From 1992 to 1993, colonization rates increased from 27% to 99.7% of unionids, and the mean number of *D. polymorpha* per unionid increased from 2.2 to 37.4. The number of *D. polymorpha* per unionid shell was related to shell length and varied among species. Four types of colonization patterns were found, each differing from the others in the relative number of colonizing *D. polymorpha*. Shell and ornamentation types were differentially colonized. Thick-shelled, ornamented species were more heavily colonized than were thin-shelled, unornamented species. Habitat alteration of the gravel bar site was profound, with the zebra mussels forming a pavement over the gravel bar. This resulted in adverse effects on the unionids. Once mussels exited the substrate, they were unable to penetrate the entangled mass of zebra mussels and pebbles. Consequently, unionids were exposed when water levels fell, and considerable mortality occurred.

Introduction

Considerable concern has been expressed about the possible negative impacts of zebra mussels (*Dreissena polymorpha*) on native unionid bivalves (Herbert et al. 1989, Mackie 1991, Schloesser and Kovalak 1991, Hunter and Bailey 1992, Mackie 1993, Tucker et [illegible] 1993). Some of the more obvious adverse impacts on unionids have been cataloged. These were summarized by Schloesser and Kovalak (1991) and include interference with valve closure and opening, impairment of normal locomotion and burrowing, smothering of siphons, interference competition [illegible] food, deformation of shells, addition of weight to the shell, creation [illegible] anaerobic conditions in water near the mollusk, and production of toxic metabolic wastes. Such adverse impacts could lead to reduction in population size or local extinction of complete faunas as has been confirmed for Lake St. Clair (Gillis and Mackie in press) where the zebra mussel was first found in North America (Hebert et al. 1989).

Tucker et al. (1993) reported on the initial stages of the invasion of *D. polymorpha* in the upper Mississippi and lower Illinois rivers. During this 1992 survey, infestation rates were low. The maximum observed number of zebra mussels per unionid was only 2.2, and the maximum observed colonization rate was 27% of the unionids. However, these authors reported a large number of young of the year *D. polymorpha* in the sample, indicating that conditions were probably favorable for increases in the numbers of *D. polymorpha*.

During 1993, the number of zebra mussels at locations in Pool 26 of the upper Mississippi River and the Alton Pool of the lower Illinois River increased dramatically. This report is concerned with results from a monitoring station located at Mississippi River mile 217, which is below the confluence with the Illinois River. I further report on previously unrecognized modes of mortality in unionids thought to be directly due to colonization by zebra mussels.

Materials and Methods

The site at Mississippi River mile 217 (Tucker et al. 1993) was selected for detailed monitoring due to its easy accessibility. The substratum consisted of a gravel bar formed from crushed rock, bricks, and other forms of rip rap washed into the river from the nearby Illinois Route 100. The station overlapped the bank edge because numerous mussels had been stranded out of water due to falling river levels. The area sampled included inundated substrate as well as recently exposed substrate and encompassed an area of approximately 240 m^2. Collections were made on November 10, 11, and 12 of 1993.

All unionid specimens containing flesh were collected. Most of these were still living, but some stranded specimens had already died. Each was identified to species (Cummings and Mayer 1992). Nomenclature follows Cummings (1991). Voucher specimens were deposited in the collections of the Illinois Natural History Survey. Each species was further classified as to the relative shell thickness and whether or not it was ornamented. Relative shell thickness was a subjective measure based on comparison of the largest available specimens of each species to each other and on shell descriptions of Starrett (1971) and Cummings and Mayer (1992).

Zebra mussels were removed from each unionid and counted. The number of zebra mussels over 19 mm maximum shell length was also recorded. The maximum shell length of each unionid was measured with a millimeter rule to the nearest mm.

Statistical analysis was performed using SAS computer software (SAS Institute 1988). Differences between means were considered statistically significant if *F* values had probabilities less than 0.05.

Results and Discussion

A total of 743 native mussels representing 18 species was collected (Table 1). Nearly all of the specimens (741) had zebra mussels attached. Two specimens of *Leptodea fragilis* were found without attached zebra mussels. In September 1992, only 27% of unionids were colonized (Tucker et al. 1993) at this location. At this same site in September 1992, Tucker et al. (1993) found 2.2 zebra mussels per unionid. In 1993, this had increased to 37.4 zebra mussels per unionid if all specimens for all species are combined.

Table 1. Unionid species collected at Mississippi River mile 217. Abbreviations: n = number of unionids collected of each species; nl = number of unionids with zebra mussels > 19 mm shell length.

Species Shell thickness/ ornamentation	n	unionid shell length (mm) mean	range sd	total number zebra mussels mean	range sd	zebra mussels (>19mm) mean	range sd	nl
Amblema plicata Thick/Ornamented	345	63.5	19-110 12.56	48.2	4-210 27.18	1.59	1-4 0.83	96
Megalonaias nervosa Thick/Ornamented	9	71.4	32-125 31.50	55.6	5-219 66.25	1.0	1.0 1.0	2
Obliquaria reflexa Thick/Ornamented	21	39.6	27-50 6.76	41.4	8-100 23.98	1.64	1-4 0.92	11
Quadrula nodulata Thick/Ornamented	4	33.5	29-38 4.20	32.5	20-49 13.53	1.0	- -	1
Quadrula pustulosa Thick/Ornamented	47	42.7	23-60 8.55	40.0	12-111 22.12	1.42	1-3 0.61	19
Quadrula quadrula Thick/Ornamented	36	47.7	25-76 15.62	46.8	5-118 28.38	1.40	1-3 0.70	10
Arcidens confragosus Medium/Ornamented	4	66.8	59-81 10.14	55.8	27-82 29.84	2.00	1-3 1.00	3
Ellipsaria lineolata Medium/Smooth	1	41		9		0		0
Lampsilis cardium Medium/Smooth	7	82.9	40-105 25.58	58.4	3-116 43.23	0		0
Lampsilis teres Medium/Smooth	44	89.4	64-111 9.73	62.5	12-136 34.16	1.36	1-3 0.63	14
Lasmigona complanata Medium/Smooth	1	92		41		0		0
Potamilus alatus Medium/Smooth	12	87.6	62-116 18.63	55.5	9-174 56.64	1.33	1-2 0.58	3
Truncilla truncata Medium/Smooth	135	41.3	18-64 7.68	26.0	1-73 13.37	1.23	1-3 0.48	43
Anodonta grandis Thin/Smooth	1	37		4		0		0
Anodonta imbecillis Thin/Smooth	4	33.0	30-36 2.45	10.0	4-21 7.79	0		0
Leptodea fragilis Thin/Smooth	168	58.9	31-108 16.98	17.1	0-86 16.80	1.48	1-4 0.82	25
Potamilus ohiensis Thin/Smooth	1	19		1		0		0
Truncilla donaciformis Thin/Smooth	1	33		26		0		0

2

Zebra mussels longer than 19 mm are almost certainly over one year old (Mackie 1993) and were present in 1992. Therefore, the rate of colonization for the previous year can be back calculated. In the present study, 30.6% of the unionids were colonized by zebra mussels longer than 19 mm. This is quite close to the 27% colonization rate reported for this same site in samples made the previous year (Tucker et al. 1993). The number of zebra mussels per unionid reported for 1992 (2.2) is also close to the number of zebra mussels over 19 mm remaining on unionids in 1993 (1.5). Therefore, a rough estimate of the prior year's colonization rate can be derived by recording the numbers of specimens over 19 mm that are present at a particular location if sampling is done in the fall.

Mackie (1991, 1993) reported that the number of zebra mussels per shell was a logarithmic function of the surface area of the unionid shell. Since measurement of surface area is difficult for unionids because of their ornate and curved shells, I used linear regression analysis to compare both log transformed and untransformed shell lengths versus number of zebra mussels. Regression analysis was statistically significant ($p < 0.05$) for all species with more than seven individuals in the sample size. Nonlinear regression analysis was also performed for all species with seven or more specimens in the sample (Figs. 1 and 2). The R^2 values for each species for all three methods were in close agreement. The two linear models and the nonlinear model are all about equally robust in their ability to predict the number of zebra mussels found on a shell of a particular length for the species examined, indicating that zebra mussels at this Mississippi River site have not approached the maximum numbers capable of being placed on shells of smaller surface area. Mackie's (1991; 1993) sample averaged 210 zebra mussels per unionid, and his results more clearly indicate the nonlinear relationship.

Data from the Mississippi River site indicate that species should be analyzed independently rather than lumped because the relationships between the numbers of colonizing zebra mussels and particular unionid species may differ. For instance, R^2 values for untransformed linear regressions were highest in *A. plicata* and *T. truncata*. They were highest for exponential regressions for *L. fragilis, Megalonaias nervosa, Potamilus alatus, Q. pustulosa* and *Q. quadrula*. For *Lampsilis cardium, L. teres,* and *O. reflexa*, the R^2 values were highest for log transformed linear regressions.

Patterns of colonization are different among the various species, and four general patterns of colonization were apparent. Type 1 was found in *Leptodea fragilis* and was characterized by zebra mussel colonization that was mostly restricted to the posterior portion of the shell immediately adjacent to the siphons, with few if any zebra mussels in the area between the posterior end and the umbos. In this type, zebra mussels on the left and right valves were about equal in number. Type 2 was found in *Lampsilis cardium, L. teres, Arcidens confragosus,* and *Anodonta grandis* and was characterized by colonization of the siphonal region along with the entire dorsal surface of the shell reaching to and usually extending anterior to the umbos. Again, zebra mussels were about as common on one side of the shell as they were on the other. The ventral surface of the shell anterior to the siphons was usually free of zebra mussels. Type 3 was found in *Q. pustulosa, Q. nodulata, Q. quadrula, O. reflexa,* and *T. truncata* and was characterized by zebra mussel colonization of the entire posterior half of the shell from the siphons to the umbo with zebra mussels being about as numerous on either valve. Type 4 was found in *Amblema plicata, M. nervosa,* and *P. alatus* and was characterized by one valve having many more zebra mussels attached to it than the other. Too few specimens of the other species were observed at this or other localities to determine what pattern of colonization was present.

Each of these patterns probably reflects the behavior of the particular unionid species relative to the substrate into which it burrows. That such diverse patterns exist has not been pointed out previously and indicates that various species present differing profiles to potential colonizing zebra mussels in the water column. The species-specific interactions between unionid mussels and their substrates alter in complex ways the actual surface area available for colonization.

There appears to be strong evidence now that relative colonization rates are related to shell thickness and ornamentation. Thin-shelled species had lower mean numbers of zebra mussels per unionid than did species with shells of medium thickness ($p < 0.05$), which in turn had fewer ($p < 0.05$) than thick-shelled species. Ornate species had more ($p < 0.05$) colonizing zebra mussels on them than did species without ornamentation. These relationships also hold for zebra mussels longer than 19 mm even though the numbers of zebra mussels present in 1992 was small and the colonization rate was much lower. There was no difference ($p > 0.05$) in

3

mean length among these various classifications of unionid mussels so the difference is not a simple reflection of the relationships between length and number of zebra mussels demonstrated earlier.

Just why thick-shelled, ornamented species should be colonized at a greater rate than thin-shelled species without ornamentation is not clear and warrants further study. Even though an explanation may not be at hand, this information is important from a management perspective. Mitigation efforts directed to preserve endangered or commercial species from extirpation by zebra mussels may be most important for thick-shelled, ornamented species because they may be more heavily colonized early in the invasion of the exotic species.

At the study site, zebra mussels not only colonized unionids but also essentially covered the entire surface of the gravel bar. Numerous druses were present, and most were attached to the substrate. They formed a pavement made up of zebra mussel shells interconnected by byssal threads. Within this mass of shells and fibers were scattered specimens of unionids. Once displaced from the substrate, these unionids were not able to reestablish their normal positions within the substrate due to the substrate being encrusted with zebra mussels. At the site, numerous specimens of unionids were found simply lying on their sides on top of the gravel bar, which is a highly unusual situation. Those that became exposed

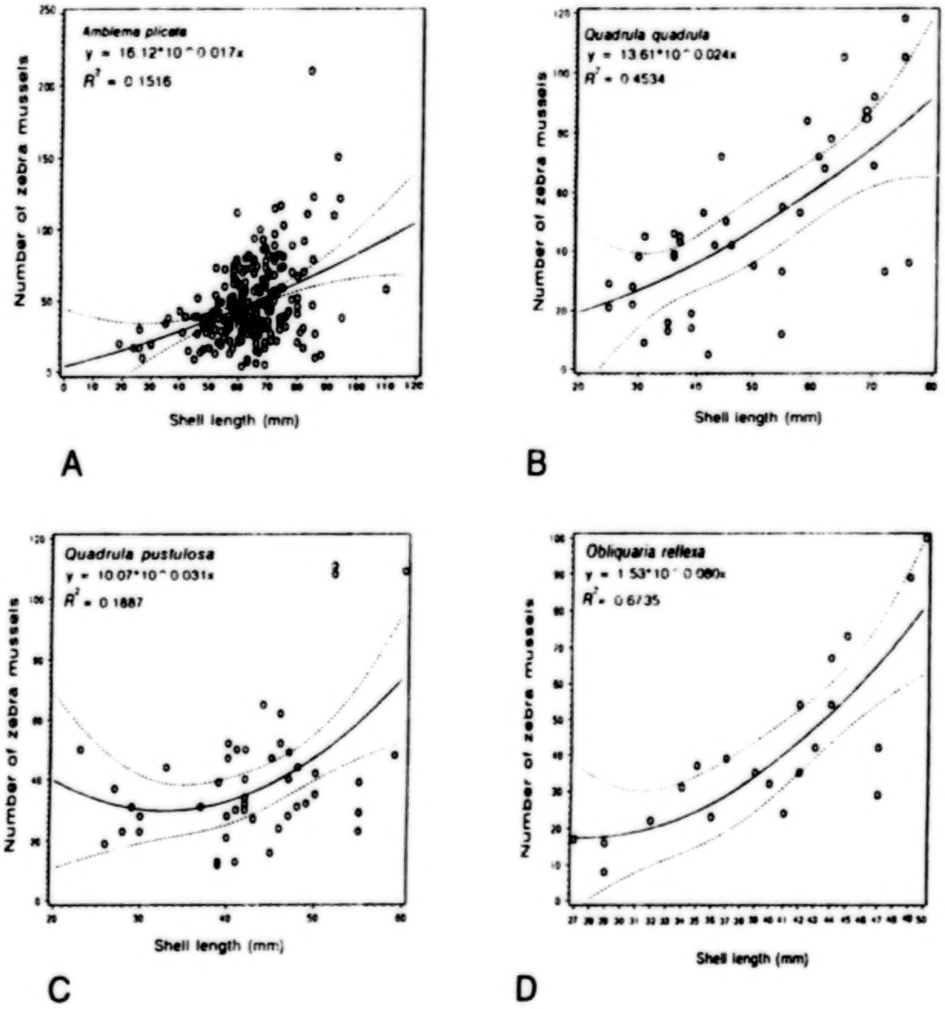

Figure 1. Relationship between shell length and the number of colonizing specimens of *Dreissena polymorpha* for species with thick, ornamented shells. A, *Amblema plicata*, B, *Quadrula quadrula*, C, *Q. pustulosa*, and D, *Obliquaria reflexa*. Dashed lines represent upper and lower 95% confidence limits.

4

when water levels fell were apparently unable to move, possibly because their feet could not penetrate the mass of zebra mussels or because the zebra mussels on their shells made them too heavy to move. They were thus unable to escape desiccation and/or temperature extremes that occurred in the late fall at this location. Many smaller specimens were found deposited in shoreline windrows formed by wakes of commercial tows and recreational boats as well as wind-generated waves. Stranding is probably a significant source of mortality at this location.

Management strategies to protect endangered unionid bivalves from the effects of zebra mussels have not been proposed, but such strategies may depend on the pattern that the zebra mussels follow in the upper Mississippi River. In Poland, Stanczykowska and Lewandowski (1993) found that zebra mussel populations peaked and then declined precipitously and remained low thereafter. If this pattern were to be repeated in the United States, then establishment of captive populations of endangered unionids for later release into native habitats might be appropriate. At present no evidence of such population crashes has been reported for the areas of North America most heavily colonized. However, close monitoring of zebra mussel population structures for changes at locations such as Lake St. Clair, Lake Erie, the Illinois River, and the portions of the Mississippi River where zebra mussels have already produced large populations will be critical in determining mitigation strategies for other regions.

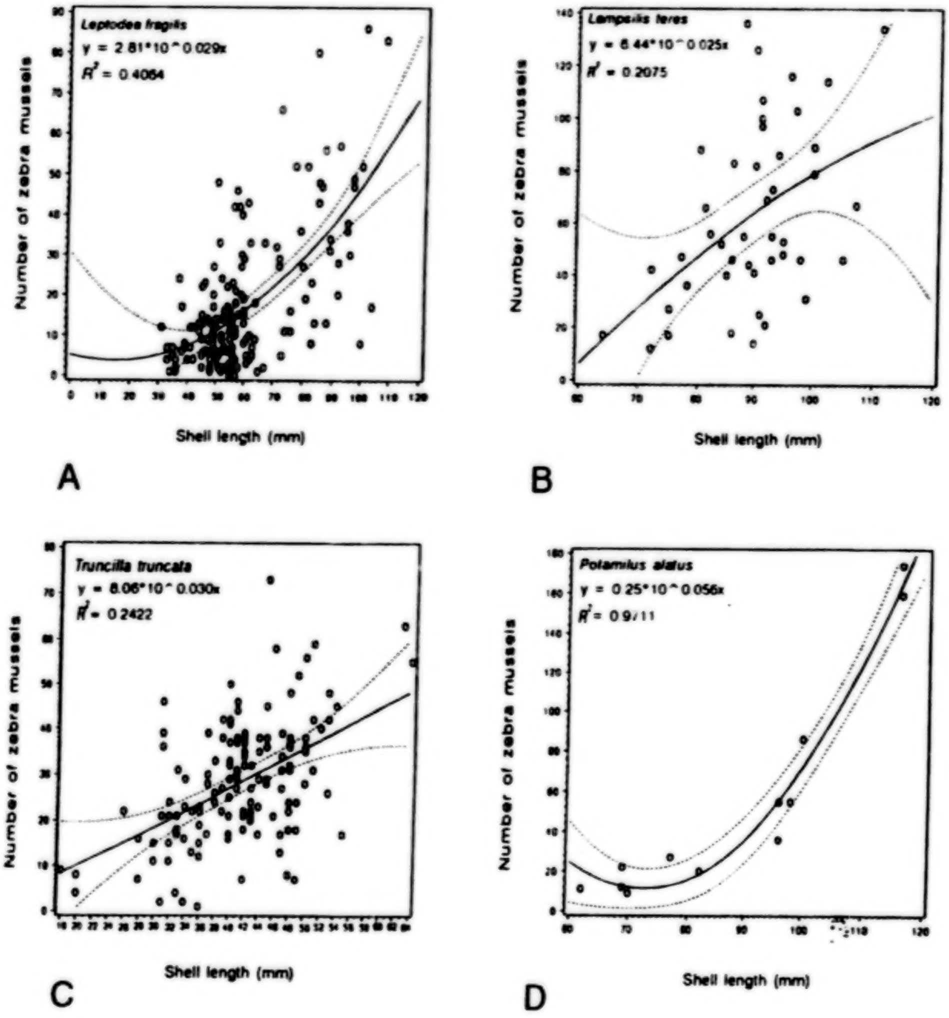

Figure 2. Relationship between shell length and the number of colonizing specimens of *Dreissena polymorpha* for species with thin, smooth shells. A, *Leptodea fragilis*, B, *Lampsilis teres*, C, *Truncilla truncata*, and D, *Potamilus alatus*. Dashed lines represent upper and lower 95% confidence limits.

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6

— NOTE —

Windrow Formation of Two Snails (Families Viviparidae and Pleuroceridae) Colonized by the Exotic Zebra Mussel, *Dreissena polymorpha*

ABSTRACT

Colonization of two species of native gastropods, *Campeloma crassulum* (Viviparidae) and *Pleurocera canaliculatum* (Pleuroceratidae), by the exotic zebra mussel (*Dreissena polymorpha*) was documented for the Mississippi River and Illinois River in Illinois. Wind- and boat-generated waves created windrowed deposits of these snails. Nearly all snails collected retained intact zebra mussels or evidence of mussel attachment.

In the fall of 1993, snails were collected from windrows deposited by wind- and boat-generated waves at Grafton on the Illinois River, Jersey County, Illinois; near the Brussels Ferry on the Illinois River, Jersey County, Illinois; and at Lewis and Clark Park on the Mississippi River, Madison County, Illinois, on November 3, 1993. The snails were the silty hornsnail, *Pleurocera canaliculatum* (Say, 1821) and the ponderous Campeloma, *Campeloma crassulum* Rafinesque, 1819. All snails were alive or recently dead and retained the operculum in life position within the aperture at the time of collection. Dead snails (i.e., those without opercula) were also present. All snails still retained either zebra mussels or their byssal threads and plaques at the time of collection. Approximately 50 snails were collected at each site. Voucher specimens of each species were deposited in the collections of the Illinois Natural History Survey.

Of 53 specimens of *C. crassulum* collected from Grafton windrows, 17 retained intact zebra mussels, 33 retained only byssal threads and plaques, and 3 had no evidence of zebra mussel attachment. Among the 35 specimens of *C. crassulum* collected in windrows at Brussels Ferry, 22 retained intact zebra mussels, and 13 others retained only byssal threads and plaques. No specimens of *C. crassulum* were found in windrows at Lewis and Clark Park. Zebra mussels were found attached to 42 of 48 specimens of *C. crassulum* collected from the Illinois River at Grafton,

A total of 51 specimens of *P. canaliculatum* were collected from Grafton windrows. Of these, 30 retained one or more intact zebra mussels, and 21 retained only byssal threads and plaques. Of 53 specimens of *P. canaliculatum* collected from windrows at Lewis and Clark Park, 48 retained only byssal threads and plaques, and 5 retained attached zebra mussels.

I also collected snails of each species at Grafton that were not in windrows but were located in/on silty sand substrate. Of 108 specimens, 42 were colonized by zebra mussels.

The number of zebra mussels colonizing available substrates in the lower Illinois River has increased markedly since the survey of unionids reported by Tucker et al. (1993). Observations at that time revealed few gastropods colonized by zebra mussels. Although flood conditions precluded quantitative sampling of snail populations for colonization rates by zebra mussels in 1993, the number of gastropods stranded following retreat of the flood waters was very large, numbering in the thousands at the Grafton boat ramp alone, which suggests that colonization by zebra mussels is extremely detrimental to native species of gastropods.

Even though many stranded specimens of snails were alive at the time of collection, they apparently were unable to move back to water even after the zebra mussels had detached. Every specimen collected in windrows had some evidence of zebra mussel attachment either in the form of attached whole mussels or byssal threads and plaques from mussels that had presumably fallen off. Dangling byssal threads become entangled in the general mass of debris of the windrow, further anchoring the snail in place. Apparently, snails were unable to escape the windrows because of this and the added weight of attached zebra mussel valves in other cases. The attached zebra mussels not only appear to imprison stranded snails within the windrows but also may make it more likely that a snail will be washed ashore. Zebra mussels may act as sails and make snails more likely to be washed ashore than snails not colonized. At present, information has been published on the effect of zebra mussel colonization on snail hydrodynamics or mobility. Consequently, my observations must be considered tentative. However, the large number of stranded specimens observed leaves little doubt that the impact of zebra mussels on the biology of native species of gastropods in the Mississippi River drainage will be significant.

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13. ABSTRACT (Maximum 200 words)

[1]The relationship between 18 species of native unionid bivalves and the exotic zebra mussel, *Dreissena polymorpha*, was explored at a monitoring site in Pool 26 of the Mississippi River. From 1992 to 1993, colonization rates increased from 27% to 99.7% of unionids, and the mean number of *D. polymorpha* per unionid increased from 2.2 to 37.4. The number of *D. polymorpha* per unionid shell was related to shell length and varied among species. Four types of colonization patterns were found, each differing from the others in the relative number of colonizing *D. polymorpha*. Shell and ornamentation types were differentially colonized. Thick-shelled, ornamented species were more heavily colonized than were thin-shelled, unornamented species. Habitat alteration of the gravel bar site was profound, with the zebra mussels forming a pavement over the gravel bar. This resulted in adverse effects on the unionids. Once mussels exited the substrate, they were unable to penetrate the entangled mass of zebra mussels and pebbles. Consequently, unionids were exposed when water levels fell, and considerable mortality occurred. [2]Colonization of two species of native gastropods, *Campeloma crassulum* (Viviparidae) and *Pleurocera canaliculatum* (Pleuroceridae), by the exotic zebra mussel (*Dreissena polymorpha*) was documented for the Mississippi River and Illinois River in Illinois. Wind- and boat-generated waves created windrowed deposits of these snails. Nearly all snails collected retained intact zebra mussels or evidence of mussel attachment.

14. SUBJECT TERMS

[1]zebra mussel, Mississippi River, Pool 26, colonization, unionid
[2]windrows, gastropod, zebra mussel

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The Long Term Resource Monitoring Program (LTRMP) for the Upper Mississippi River System was authorized under the Water Resources Development Act of 1986 as an element of the Environmental Management Program. The mission of the LTRMP is to provide river managers with information to maintain the Upper Mississippi River System as a sustainable large river ecosystem given its multiple-use character. The LTRMP is a cooperative effort by the National Biological Service, the U.S. Army Corps of Engineers, and the states of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.

END

09/25/96

y zebra mussels. Although flood conditions precluded
f snail populations for colonization rates by zebra
mber of gastropods stranded following retreat of the
arge, numbering in the thousands at the Grafton boat
sts that colonization by zebra mussels is extremely
pecies of gastropods.
tranded specimens of snails were alive at the time
arently were unable to move back to water even after
etached. Every specimen collected in windrows had
mussel attachment either in the form of attached
threads and plaques from mussels that had
Dangling byssal threads become entangled in the
of the windrow, further anchoring the snail i
ils were unable to escape the windrows because of
ht of attached zebra mussel valves in other cases.
els not only appear to imprison stranded snails
also may make it more likely that a snail will be
ussels may act as sails and make snails more likely
n snails not colonized. At present, information has
ffect of zebra mussel colonization on snail
ty. Consequently, my observations must be
However, the large number of stranded specimens

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[2]Colonization of two species of native gastropods, *Campeloma crassulum* (Viviparidae) and *Pleurocera canaliculatum* (Pleuroceridae), by the exotic zebra mussel (*Dreissena polymorpha*) was documented for the Mississippi River and Illinois River in Illinois. Wind- and boat-generated waves created windrowed deposits of these snails. Nearly all snails collected retained intact zebra mussels or evidence of mussel attachment.

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